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MUNICIPAL

DESCRIPTION OF PLANT AND
TREATMENT PROCEDURES -
HAMILTON WATER WORKS
PURIFICATION PLANT.

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A DESCRIPTION OF PLANT AND TREATMENT PROCEDURES
OF
THE HAMILTON WATER WORKS PURIFICATION PLANT
IN
TWO PARTS

PART ONE: DESCRIPTION OF PRE TREATMENT PLANT FACILITIES AND TREATMENT PROCESS.

PART TWO: PERTINENT DATA RELATING TO PLANT EQUIPMENT, CHEMICALS USED, PUMPS, RESERVOIR CAPACITIES Etc., WITH A CHEMICAL ANALYSIS OF THE TREATED WATER APPENDED.

RLL **Revised March 1973**

SOURCE

The source of Hamilton's water supply is Lake Ontario. A "Low Lift" pumping station is located at Lakeland Beach, supplying untreated lake water to the main treatment plant through an 84 inch diameter concrete conduit. The treatment plant is approximately 1800 feet inshore from the Low Lift Station.

Lake water enters the Low Lift station through three intakes of varying lengths which extend into the lake 2200 to 3100 feet from the shoreline. The intakes are 48, 60 and 96 inches in diameter respectively, each terminating in a crib structure on the lake bottom 27 to 30 feet below the surface. Lake water enters a "wet well" chamber in the Low Lift Station, passes through bar screens and thence through rotating screens of one-quarter inch mesh fabric (bronze) which removes weeds, fish and other debris from the water before it enters the pump suction well. The raw water is then pumped through an 84 inch diameter concrete pipe to the treatment plant.

Flow to the plant is measured by means of two "Venturi Tubes" which are devices inserted into and forming an integral part of the pipe lines supplying the treatment plant facilities.

PRE-TREATMENT PLANT FACILITIES AND EQUIPMENT

Newly constructed pre-treatment facilities, completed in 1972, are designed to increase the plant hydraulic capacity to 200 million imperial gallons per day. These facilities consist in the main of the following:

1. Pre-chlorine building, in two sections, one of which houses the liquid chlorine evaporators, gas chlorinators, chlorine solution injectors and control equipment for application of chlorine to the water; the other section is a storage area for the one ton chlorine cylinders, and is equipped with an overhead monorail travelling hoist for handling the cylinders.

2. Two separate treatment "Modules", each consisting of two "Flocculator" tanks fitted with rotary mixing devices, are installed. There are also four settling tanks through which the water flows before reaching the filtration building, which houses the sand/anthrafilt filters.

TREATMENT PROCESS

In the treatment process proper, the water flows first through "Flash Mixing" chambers which are fitted with mechanical mixing devices. These serve to create considerable turbulence in the water, the purpose being to rapidly disperse the liquid alum previously injected into the flow. Alum is applied primarily to remove as much turbidity as possible from the raw water before it reaches the filters. This turbidity is due to the presence of silt, mud, algae and other particulate matter. The alum particles form a nucleus around which the "floc" coalesces into larger particles which in later stages of flow through the settling basins sink to the bottom, resulting in removal of most of the turbid matter prior to the last stage in the mechanical treatment process, filtration.

On leaving the flash mixing chambers the water enters the flocculator tanks, its velocity being considerably decreased as it flows through the tanks.

The flocculator tanks are provided with mixing devices which impart movement and energy to the water, assisting in the growth and coagulation of the floc particles. From the floc tanks the water enters the much larger settling basins, in which settling out of the entrapped, flocculated suspended matter occurs. The settling basins are about 17 feet in depth each having a capacity of two and a half million gallons.

In addition to alum, chlorine is applied to the raw water at approximately the same point as the alum. This is "Prechlorination". The flow of raw water from the settling basins enters the filter building in which are located a total of 24 filters. These are the "Rapid Gravity" type, utilizing a dual filter media, sand and Anthrafilt, a typical cross-section of which is shown in Fig. 1.

FILTER CONSTRUCTION

A filter is basically a concrete structure on the floor of which is placed a gridwork of 4-inch diameter pipes, one end of each being capped, the other end terminating in a cast iron manifold. On the under side and along the full length of each pipe are small holes through which the filtered water flows. This piping arrangement is known as the filter underdrain. Overlying the filter underdrains are layered beds of various sized gravels, grading from about 2½ inch in size on the bottom to the "pea gravel" at the top, ¼ inch in size.

Directly over the pea gravel is the bed of filter sand, approximately 13 inches in depth. On top of the sand rests a layer of Anthrafilt 15 inches deep. Anthrafilt is a trade name for a special grade of anthracite coal, crushed and ground to a specific grain size; it is coarser than sand and has a lower specific gravity. The filters are known as "dual media" types, containing both sand and Anthrafilt. The purpose of dual media filters is to increase efficiency by achieving longer filter runs and a more even distribution of "head loss" through the bed than would be accomplished by the use of sand alone as a filter medium. The theoretical ideal filter medium would be a material which graded from coarse to fine in a downward direction, and stayed that way. Unfortunately, with any one homogeneous material such as sand (or Anthrafilt) alone the particles settle out after expansion and washing with the larger, heavier grains on the bottom, grading upward to the smaller, lighter particles on top, which is the opposite to what is desired. The use of a dual media filter improves this situation somewhat since the larger but lighter grains of Anthrafilt settle out on top of the sand bed after washing. The small pea gravel serves to support the whole of the filter media, preventing it from being carried down through the coarser gravels to the underdrains. The larger gravels above the underdrains serve a two-fold purpose in:

1. Effecting an even distribution of the water downwards to the underdrains during the filtering cycle; and

2. Ensuring the same action during the "Backwash" cycle when the water flow is reversed and rises upwards through the bed, expanding the sand/Anthrafilt about 50%.

A few inches above the top of the Anthrafilt Bed is positioned a gridwork of pipes and rotating tubular arms which constitute what is known as the surface wash equipment. There are 6 rotating members in each filter, each of these "sweep arms" having a series of jet nozzles along their length. During the backwash operation the arms rotate through the expanded sand and anthrafilt, water under 80 - 85 psi being ejected through the nozzles. The turbulence thus created within the expanded filter media assists materially in the overall effectiveness of the backwash procedure, the purpose of which is to expand the sand/anthrafilt, forcing upwards the coagulated particulate matter entrapped in the filter media. As this material floats to the surface it overflows into the wash troughs, which discharge the wash water to waste. The arrangement is shown in Fig. 3. Each filter is equipped with the necessary valving to control the flow of water into and out of the filter as well as a valve to admit wash water and a smaller valve to control the flow of water to the surface wash equipment. Fig. 3 illustrates the action which takes place during a backwash operation. During the filtering cycle (See Fig. 2) the pre-treated water enters through the influent valve, flows downwards.

through the filter bed into the underdrain laterals and thence out through an effluent valve to a common header, which collects water from all filters. This filter effluent header terminates in a "Clear Well" reservoir from which it flows to the suction side of the station "High Lift" pumps. These pumps deliver the finished water to the city distribution system.

CHLORINATION - DE-CHLORINATION - AMMONIATION - FLUORIDATION

The brief description given thus far of the treatment process has mentioned the use of chlorine. Clarification of water can be and is achieved by the usual methods of application of alum or other coagulating agents, detention time in flocculating tanks and settling basins and finally, filtering. Water subjected to such a treatment would no doubt be clear and sparkling to the eye. It would not necessarily, however, be considered safe to drink. A "Safe" water is one free of pathogens (disease causing organisms) or at least containing so few that no threat to health is considered likely. Chlorine is the chemical most used in water treatment plants for purposes of disinfection, i.e., "destruction of bacteria". Chlorine serves other purposes as well i.e., oxidation of metals such as iron, manganese, destruction of taste and odour producing substances in water, acts as an aid to coagulation and inhibits the growth of algae and other organisms. Chlorine is delivered to this plant in liquid form under pressure in one ton cylindrical steel containers. Three cylinders are placed on a weigh scale at one time and connected up in parallel to the chlorine evaporators. An evaporator is basically a steel tank which receives the liquid chlorine from the cylinder. The evaporator chlorine tank is immersed in a hot water bath held at a temperature of approximately 150°F. With such an arrangement, much higher rates of withdrawal of chlorine gas are possible than by feeding gas direct from chlorine cylinder to the chlorinator. The maximum rate of withdrawal of gas from a ton cylinder is about 500 lbs. per 24 hours. Any attempt to use higher rates than this would cause freezing up of the gas discharge line. By interposing an evaporator between cylinder and chlorinator and heating the liquid chlorine by means of the hot water bath, the maximum rate of withdrawal of gas from the evaporator discharge line is (with our units) approximately 8000 lbs. per 24 hours.

In the pre-treatment process, chlorine is applied at the raw water inlet to the flocculator tanks, the method of application being as follows: chlorine gas flows from the evaporator discharge line to the chlorinator unit, which meters and regulates the dosage in accordance with two variables - the chlorine "demand" of the raw water and the volume of flow. Selection of the proper dosage is dependent on the quality of the raw water, types of contamination present, etc. From the chlorinator the metered gas flow is fed to an "injector", a device through which water flows at high pressure and so constructed as to produce a negative pressure at the gas inlet connection. The chlorine gas is thus drawn into the injector, combined with the water flow through the unit and the resulting chlorine solution piped to the point of application. The strength of this solution is determined, as previously mentioned, by two variables - chlorine demand and flow rate. Chlorine is a strong oxidizing agent and when applied to a water containing organic matter, bacteria, iron, manganese, free ammonia etc., combines chemically with these substances and is, in a sense, "used up"; hence the term "chlorine demand". The amount of chlorine necessary will vary considerably, depending on the quality of the water so treated. The usual practice is to apply sufficient chlorine to accomplish its purpose and still have an amount remaining as a chlorine "residual", either in the free or combined state. This is achieved by means of various types of instrumentation and control devices. If, for instance, the quality of the raw water having been determined by chemical and bacteriological analysis, it is desired to maintain a pre-chlorine residual near the point of application at some value such as 1 ppm (one part per million = 1 part chlorine to 1 million parts water) the appropriate instrumentation is set up to maintain this value, within tolerable limits. Briefly this is accomplished as follows: The chlorinated water near the point of application is continuously monitored through a chlorine analyser, which senses the actual residual. The output from the analyser is an electric current of very small magnitude which is transmitted to an instrument known as a chlorine residual recorder-controller.

The controller maintains a continuous chart record of the residual value and re-transmits the same signal back to a vacuum control device on the chlorinator. As the signal varies in strength with the actual chlorine residual value, the vacuum control device operates to increase or decrease the rate of feed of chlorine gas through the chlorinator, to injector, to point of application, and so maintains the chlorine residual within close limits of the "set-point" desired. This is known as residual control. The chlorinator feed therefore will vary in accordance with the chlorine "demand" of the raw water. Another factor affecting the magnitude of the dosage is of course the rate of flow. If the flow remains the same, the only factor which will affect a change in feed will be the chlorine "demand". As the flow rate changes, the controls on the chlorinator will vary the rate of chlorine feed accordingly, since the chlorinator output is "paced" by the raw water flow. This is "flow control", and is superimposed on the "residual control" as required by changes in the flow rate. The signal for this control mode originates at the Venturi tube which measures the actual flow of raw water to the pretreatment facilities.

With the present raw water quality prevailing at our source, this initial pre chlorine dosage is generally sufficient to perform its required functions and ensure a reasonably safe value of chlorine residual through the treatment process and on into the distribution system.

POST TREATMENT

If, after filtration and upon entering the clear well reservoir, the residual value is found to be either too high or too low, corrective measures are taken. Should the residual be too high, sulphur dioxide is applied to remove excess chlorine. If the residual is too low, additional chlorine is applied to bring the residual up to the desired value. This is "Post Chlorination" and is accomplished by using the same type of apparatus and instrumentation as in the pretreatment stage.

Anhydrous Ammonia is another chemical used in the post treatment phase. The ammonia combines chemically with any remaining "free" chlorine to form a compound known as "chloramine". By having the chlorine residual in the "combined" form instead of the "free" form, the possibility of complaints of chlorinous tastes or odours is greatly reduced. In addition, chloramines do not combine with other matter in the system to create tastes or odours. Chloramines do not have as powerful an oxidizing effect as does chlorine in the free state, but they persist longer in the distribution network.

FLUORIDATION

Hamilton's water is fluoridated, the particular form of fluoride used being in the form of hydrofluosilicic acid. The chemical is precisely metered into the water so as to raise the fluoride level up to approximately 1 ppm. The natural fluoride concentration of lake water at this location is between 0.15 and 0.25 ppm. Application of the various chemicals in the treatment process is automatic and so programmed as to ensure the best possible finished water quality.

PERTINENT DATA

Water supply source - Lake Ontario, at Lakeland Beach

Raw Water Intakes -
1 - 48" Diameter, 2100 ft. from shoreline
1 - 60" Diameter, 3000 ft. from shoreline
1 - 96" Diameter, 3100 ft. from shoreline

Screening Equipment - Bar screens in Low Lift intake chamber and 3 Travelling-type screens before Low Lift pump suction well.

Low Lift Pumps -
Total of 6
4 - Rated at 50 MGD each, 28 ft. head
2 - Rated at 36 MGD each, 28 ft. head
Pump drive motors - Line start, induction, 2400 volt.

Pump Control - Normally remote operated through "Visicode" supervisory equipment from Purification Plant or may be operated manually at site. Status of all main equipment components, pressure and flow data, well levels, travelling screen differential, etc. displayed visually on consoles at No. 1 District Pump Station Control Center.

Pre-Treatment Facilities -

Raw water received from Low Lift Station through 84" diameter concrete pipe. Provision for future line of 108" diameter.

2 - Pre-treatment modules, each consisting of 2 flocculation tanks.

4 - Settling basins - Capacity 2½ MG each.

24 - Dual media filters, sand/anthrafilt, presently operating up to 8.0 MGD each.

Filter area - 1425 sq. ft. each filter.

Rate of Flow control - Pneumatic

Underdrains - cast iron, 4" diameter on 12" centres with 9/16" bushed holes on 6" centres.

Gravels - 5 layers, 2½" to pea gravel. Gravel depth 20".

Filter Media - 13" Sand, topped with 15" Anthrafilt. Sand effective size - 0.55 mm. Anthrafilt effective size - 0.70 mm.

Filtration Rate - Presently 2.92 GPM per sq. ft.

Wash Troughs - Pre-cast concrete, 26" wide, on 72" centers. Lip of trough is 42" above top of anthrafilt bed.

Surface Wash Equipment -

East wing, straight tubular rotating arms

West wing, curved arms.

Wash Water - Elevated tank of concrete construction integral with filter building structure holds 168,000 gallons. Supplied by 2 pumps of 2000 GPM and 2 pumps of 4000 GPM capacity each.

Filter Wash Rate - 12" rise through bed for 2 minutes (9000 GPM) followed by 27" rise rate (20,500 GPM) for 4 - 5 minutes.

Clear Water Reservoir -

6 million gallon capacity. Feeds direct to High Lift Pumps.

Chlorination - Compound Loop system i.e., automatic as regards chlorine residual and rate of flow. Pre Chlorine applied at inlet to floc tanks. Post Chlorination if necessary in filter effluent before entry to clear well.

Pre chlorine residual control point usually between 1.2 and 1.5 p.p.m. total combined (quite often running 75% or more as free).

Post chlorine residual control point 0.6 p.p.m.

Ammoniation - Storage tank capacity 11,000 lbs.

Ammoniator equipped with vacuum control linked to High Lift Pump discharge flow signal.

Ammonia dosage - 0.10 p.p.m.

Application point - Clear Well reservoir inlet.

Fluoridation - Form used: H_2SiF_6 (Hydrofluosilicic Acid).

Storage tank capacity - 10,000 gallons.

"Day" tank capacity - 500 gallons, transfer from storage tank to day tank by compressed air. Fluoride applied at entry to clear well reservoir by means of diaphragm metering pump. Dosage regulated by same pacing signal as applied to ammoniator. Dosage set at approximately 0.8 p.p.m. to raise fluoride level to 1.0 p.p.m. since lake water fluoride level is between 0.15 and 0.25 p.p.m.

Coagulant - Liquid alum used. (Al_2O_3 - 8.3%)

Introduced into water through metering pump whose output is paced by raw water flow signal.

Dosage generally 10 p.p.m. when raw water turbidity is from 5 to 25 p.p.m.; 15 p.p.m. with raw water turbidity of 25 to 50 p.p.m.; 20 p.p.m. when turbidity exceeds 50 p.p.m. Liquid alum stored in two wood stave tanks having plastic liners each tank of 10,000 gallon capacity.

Sulphur Dioxide - Applied to filter effluent as required to ensure a plant discharge chlorine residual no greater than 0.7 p.p.m. in total combined form. Equipment and instrumentation for application of SO_2 identical to that for post chlorination.

High Lift Pumps - Total of 6 units installed at present

Pump Capacities:

Unit No. 1 - 17 MGD at 235 ft. Head
Unit No. 2 - 30 MGD at 235 ft. Head
Unit No. 3 - 30 MGD at 235 ft. Head
Unit No. 4 - 30 MGD at 235 ft. Head
Unit No. 5 - 35 MGD at 235 ft. Head
Unit No. 6 - 35 MGD at 235 ft. Head

Pump drives for units 1 to 4 are line start synchronous motors, 2400 volt. Drives for units 5 and 6 are synchronous motors, line start and 13,800 volt.

Surge Suppressors - Two "Pelton" type 14" valves which open on total power outage to High Lift pumps. On complete pump shutdown system surge is diverted through suppressor valves to clear well reservoir for approximately 20 seconds, then valves reclose.

Discharge Mains - Three 48" primary headers exit from main pumping station and are further interconnected to smaller mains of 36", 30", 20" and 18" diameter which supply distribution system.

Booster Pump Stations -

Total of 8 at present, supplying Districts 2, 4, 5, 6, 7, 8, and 11.

District 3 supplied from district 5 through pressure reducing valve.

System Reservoir Capacity -

Low Level area (District 1) - 90 MG

Middle Level area (District 2) - 28 MG

Mountain Area (Dsitrict 5) - 50 MG

Main Station Power Supply -

2 H.H.E.S. circuits, 13.8 KV into outdoor sub station plus a tie line to Sewage Treatment Plant sub.

Installed transformer capacity at Purification Plant sub -2-6000 KVA units, 3 phase, 13,800/2400 volts.

Low Lift Station Units -

2 - 3000 KVA 3 phase, 13,800/2400 volt transformers.

LABORATORY CONTROL - The Hamilton-Wentworth Municipal Laboratory carries out continuous tests on a daily basis to ensure that the water quality complies with desired standards, and that a finished water of highest clarity, odour and taste free, is delivered to the distribution system. Chemical dosages applied in the treatment phase are based largely on the results of such Laboratory tests and determinations.

Chemical Analyses:		mg/1
Total dissolved solids		210.
Silica, as SiO_2		0.0 - 0.5
Iron, as Fe		0.0 - 0.02
Aluminum, as Al		0.0 - 0.1
Calcium, as Ca		50.
Magnesium, as Mg		8.
Sodium, as Na		13.
Potassium, as K		1.5
Sulfate, as SO_4		24.
Chloride, as Cl	average:	28.
	range:	26. - 31.
pH - varies seasonally and with treatment, usual range:		7.2 - 7.6
Alkalinity, as $CaCO_2$	average:	83.
	range:	70. - 94.
Hardness, as $CaCO_2$	average:	137.
	range:	130. - 155.

Fluoride, is added to raise the level in raw water to 1.0

WATER TEMPERATURE

In addition to seasonal changes the Hamilton water exhibits rapid temperature changes in summer because of the fluctuating level of the thermocline in the lake.

The following table shows the monthly averages for five years of observation (1965-69). The maxima and minima shown are the highest and lowest individual readings observed for the indicated months. The temperature readings are taken hourly at the Water Purification Plant.

WATER TEMPERATURES, °F.

Month:	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Average:	35	33	35	38	44	49	50	54	59	48	42	37
Maximum:	38	37	38	44	48	61	68	72	66	61	47	42
Minimum:	32	32	32	32	39	43	41	41	42	41	37	33

METRIC CONVERSION - SAMPLES

1 inch = 25.4 mm or 2.54 cm
48 inches = 122 cm
60 inches 152.5 cm
84 inches = 213.5 cm
96 inches = 244 cm

1 foot = 30.48 cm
30 feet = 9 m (metres)
3100 feet = 945 m

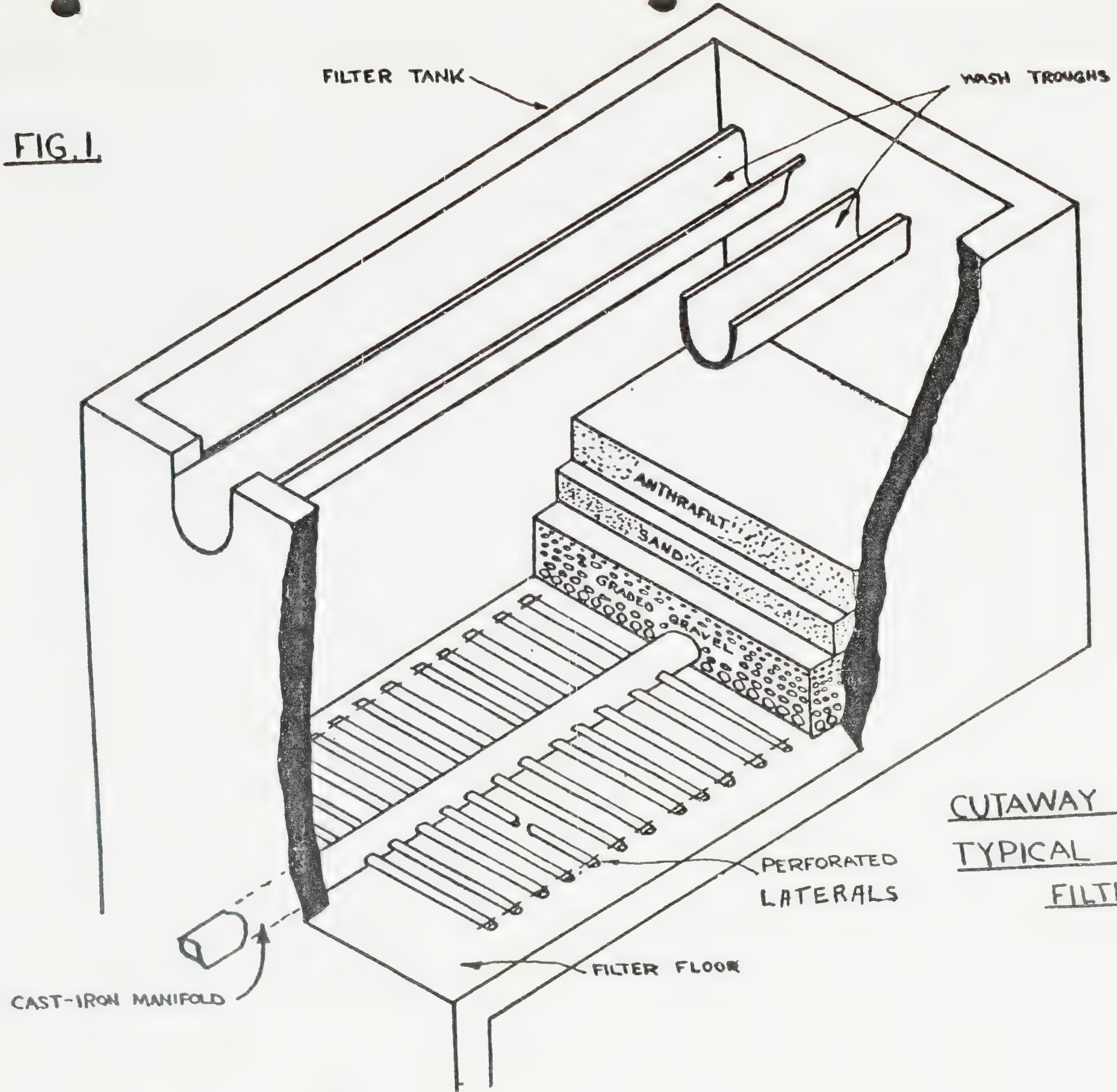
1 gallon = 4.546 litres
1 million gallons = 4545 m^3 (cubic metres)
1 m^3 = 1000 litres (ℓ)
2.92 GPM (gallons per minute) per square foot - 143ℓ per minute per square metre

2.2 lbs. = 1 kg
500 lbs. = 225 kg

P.P.M. (parts per million) = mg/ℓ

Pressure 1 kg/cm^2 = 14.19 lbs per square inch
80 p.s.i. = 5.5 kg/cm^2

FIG. 1.



CUTAWAY VIEW OF TYPICAL RAPID SAND FILTER.

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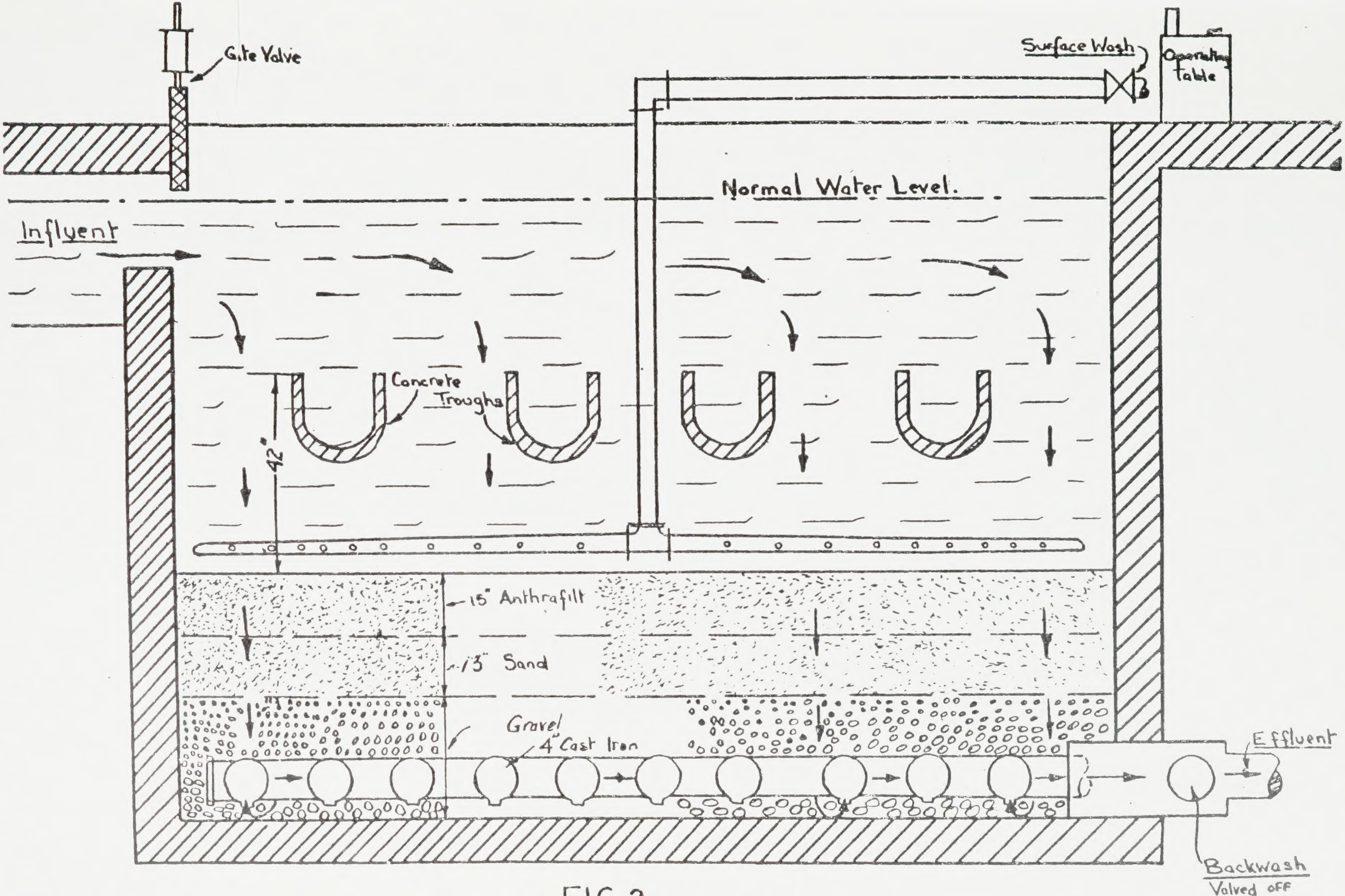

FIG 2

FILTER IN OPERATION

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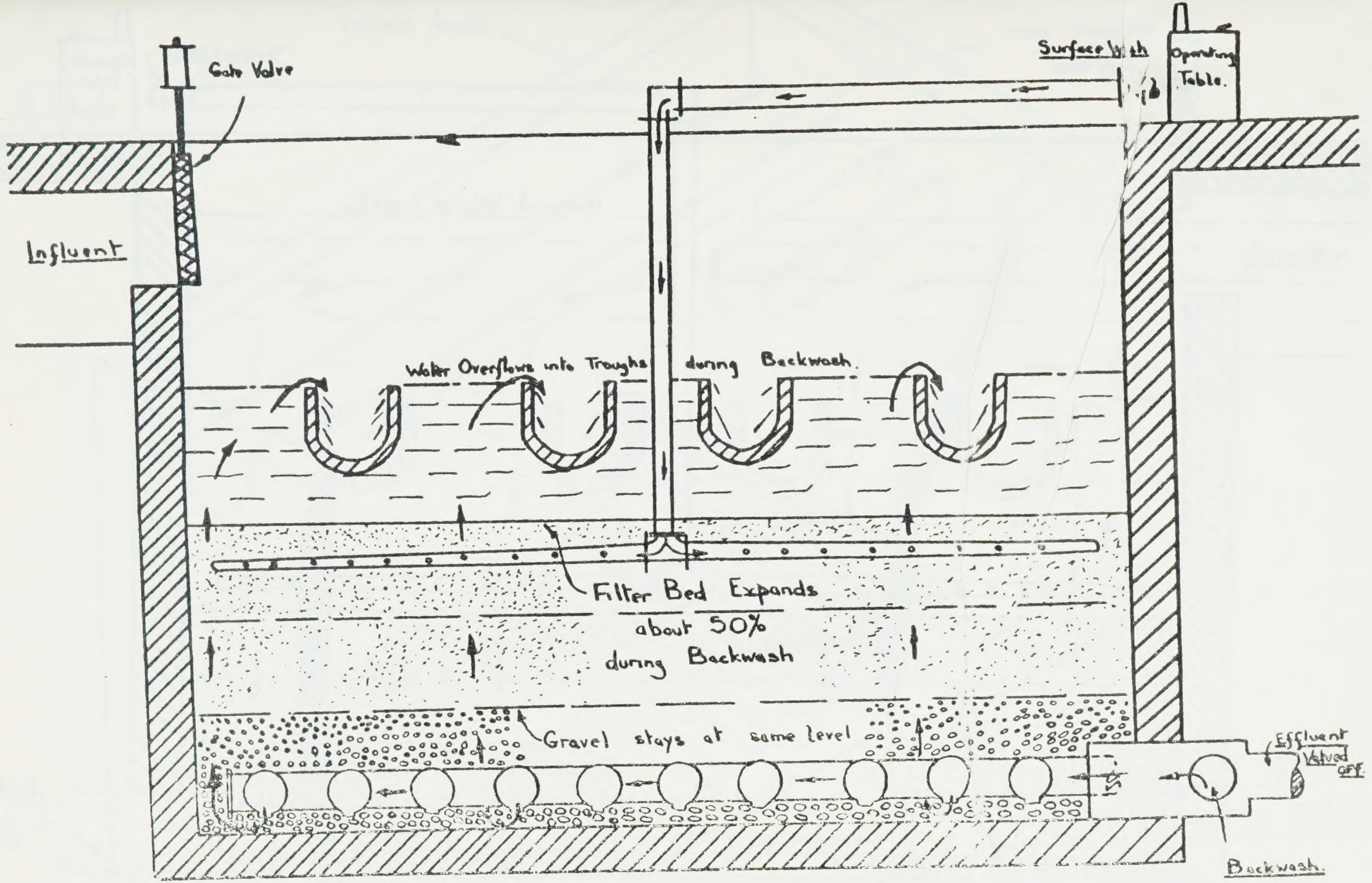
Gate Valve
Influent
Surface Wash
Operating Table.
Water Overflows into Troughs during Backwash.
Filter Bed Expands about 50% during Backwash
Gravel stays at same level
Effluent Valved off.
Backwash.

FIG 3

BACKWASHING A FILTER.

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